TEMPORARY THRESHOLD SHIFTS AND ATTENUATION EFFECTS OF THE ER-15 EARPLUG

An Honors Thesis (HONRS 499)

by

Beth A. Eckstein

Thesis Advisor
Dr. Claudia Updike

Claudia Updike

Ball State University

Muncie, Indiana

November 1992

Expected Date of Graduation
December 20, 1992

ABSTRACT

The purpose of this study was to evaluate the possible protective effect of the ER-15 earplugs on the hearing of musicians. The subjects played amplified rock and roll music with and without earplugs. The pre- and post-exposure hearing thresholds were analyzed for the presence of temporary threshold shifts. The attenuation effect of the earplugs was also analyzed. The results of this research were somewhat inconsistent and unexpected. Wearing the ER-15 earplugs did not seem to significantly reduce the effects of amplified music exposure on hearing. The ER-15 earplugs were designed to provide 15dB of attenuation at each frequency. The expected 15dB of attenuation was not present at each frequency, however, the differences were only significant at one frequency. Therefore, the ER-15 earplug provided the appropriate amount of attenuation it was designed for at all of the frequencies tested except one.

INTRODUCTION

As our world has become more populated through the decades, it has also become noisier. Some common sources of noise include industry, transportation, household appliances, and entertainment such as music. Noise affects us physically and psychologically. Stemming from concern over these effects, the United States Occupational Safety and Health Administration (OSHA) has set standards for the number of hours a day it is safe to be exposed to certain sound levels. The following information presents the limits in hours per day and the sound levels in dB (Berger 1986):

Duration per day (hours)	Sound level dB A slow response
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Music and its effects on the musicians and the listeners has been one focus of noise research. There are several studies that have been done involving the hearing of symphony orchestra musicians. Ostri, Eller, Dahlin, and Skylv (1989) found that 58 percent of the classical musicians studied had a hearing impairment. The typical audiogram had a notched curve at higher frequencies which is normally attributed to occupational noise exposure. They concluded that symphonic musicians suffer from hearing impairment and that the impairment might be ascribed to symphonic music.

In another study, Johnson, Aldridge, Sherman, and Lorraine (1986) found that musicians' hearing appeared no poorer than nonmusicians' hearing which suggested no major hearing loss from musician exposure to orchestral noise. Karlsson, Lundquist, and Olaussen (1983) found that the tone thresholds of symphony orchestra musicians did not differ from the reference values although the actual sound exposure in some situations exceeded the permitted sound levels applied to industrial noise. They suggested that the sound exposure criteria for industrial noise are not valid when discussing such sounds as are produced by acoustic instruments in a symphonic environment.

Less research has been done to examine the effect of amplified rock and roll music on the hearing of both the musicians and the listeners. The listeners may be exposed to the high intensity live music of a band once a year at a concert or once a week at a club. The musicians are exposed to these potentially dangerous intensity levels on a regular basis. They spend several hours a week practicing alone, with the band, and playing out in clubs. Most musicians experience a temporary threshold shift after playing a rock and roll concert. Jerger and Jerger (1970) reported shifts in excess of 15dB in at least one frequency in the range between 2000 and 8000 Hz. It is known that temporary threshold shifts can lead to permanent threshold shifts. This places rock and roll musicians at a high risk for permanent hearing loss.

It would seem that musicians would recognize the effects of their music on their hearing and be motivated to use hearing protective devices. There are problems associated with conventional earplugs that have discouraged those who need them most from wearing them. These conventional earplugs produce 10 to 20dB of extra high frequency attenuation, have a large occlusion effect, and attenuate more than is necessary (Etymotic Research 1991). The new ER-15 Musician's Earplug has been designed to attenuate sounds at all frequencies by a similar amount allowing the wearer to hear more naturally. The fidelity of the sound is preserved, and it reportedly does not sound muffled. The response curve of the ER-15 is flatter so it attenuates sound with greater accuracy and without changing tone quality. The ER-15 is not intended for maximum attenuation (Etymotic Research 1991).

Amplified rock and roll music is usually played at very high sound levels. A musician wearing earplugs should be able to safely play for longer periods of time. Without protection at 105dB, the limit is one hour. The limit is four hours if wearing the ER-15 earplug (Etymotic Research 1991).

The purpose of this study was to evaluate the possible protective effect of the ER-15 earplugs on the hearing of musicians.

METHOD

SUBJECTS

The subjects consisted of four male musicians ages 19 to 22 years who volunteered for this study. They are referred to as subjects 1, 2, 3, and 4. They were asked to fill out questionnaires concerning their background information, and their responses may be found in Table 1.

EQUIPMENT

A practice room was provided by the Ball State School of Music. Figure 1 is a diagram of the room with the relative dimensions and positions of each subject during a routine practice session.

The testing was performed in an IAC sound treated room. A Beltone 2000 audiometer, calibrated to ANSI 1969 standards, was used to obtain hearing thresholds. Tympanograms were obtained with a GSI middle ear analyzer. A Larson Davis Labs Model 700 dosimeter was used to measure sound pressure levels in the practice room. The earplugs used were ER-15 custom-made musician earplugs designed by Etymotic Research.

PROCEDURE

The testing was done in two sessions. During the first session, hearing thresholds at the octave frequencies from 250 to

8000 Hz were measured on all four subjects. The musicians then went to the practice room in the Music Building. They played amplified rock and roll music for two hours without hearing protectors. The sound pressure levels were measured at the ear level of each musician and at various locations around the room. After two hours of playing, each subject had his hearing re-evaluated. The hearing thresholds, pre- and post-exposure, were analyzed to determine if there were significant differences. Ear impressions were then made so that the custom-made earplugs could be ordered.

During the second session, the subjects' hearing was retested and compared to their pre-exposure thresholds from the first session. The custom-made musician earplugs were properly inserted by the experimenter, and the hearing thresholds were retested to determine the attenuation effects of the ER-15 earplugs at the octave frequencies from 250 to 8000 Hz. The musicians went to the same room in the Music Building as they did the first time. Before playing, their thresholds were measured at 3000, 4000, and 6000 Hz with a Maico MA40 audiometer in the music room. Their thresholds were within 5dB of the measurements from the IAC sound treated room. This time they played with earplugs in. After one hour, the earplugs were removed and the hearing thresholds were measured in the same room using a Maico MA40 audiometer. The musicians played for one more hour without the earplugs. Their hearing was then retested. The post-exposure thresholds with and without earplugs were compared. The subjects were asked to fill in surveys regarding their subjective impressions of the earplugs and the experiment. This information is contained in Table 2.

TABLE 1.

QUESTIONNAIRE CONCERNING BACKGROUND INFORMATION

SUBJECT	#1	#2	#3	#4
AGE IN YRS	22	22	19	22
INSTRUMENT	GUITAR	GUITAR	BASS GUITAR TRUMPET	SOUND BOARD
#YRS PLAYED INSTRUMENT	8	6	9	1
#HRS/WK PRACTICE WITH BAND	6-8	4-8	4	3
#HRS/WK PRACTICE ALONE	7	3-6	14	0
FREQ OF RINGING SENSATION AFTER PLAYING	ALL THE TIME	ALL THE TIME	RARELY	SOMETIMES
RINGING SOUNDS LIKE	CONSTANT HUM	BUZZING LIKE FLORESCENT LIGHT	HIGH PITCHED	-------
RINGING LASTS	12 HRS	8 HRS	30 MIN	-------
OTHER PROBLEMS LIKE HEADACHES AFTER PLAYING	NEVER	SOMETIMES	RARELY	NEVER
PROBLEMS UNDERSTANDING SPEECH IN NOISY ENVIRONMENTS	NO	SOMETIMES	SOMETIMES	NO
PROBLEMS UNDERSTANDING SPEECH IN QUIET ENVIRONMENTS	NO	SOMETIMES WOMEN ON PHONE	NO	NO
USED HPDS WHEN PLAYING	NO	NO	NO	NO

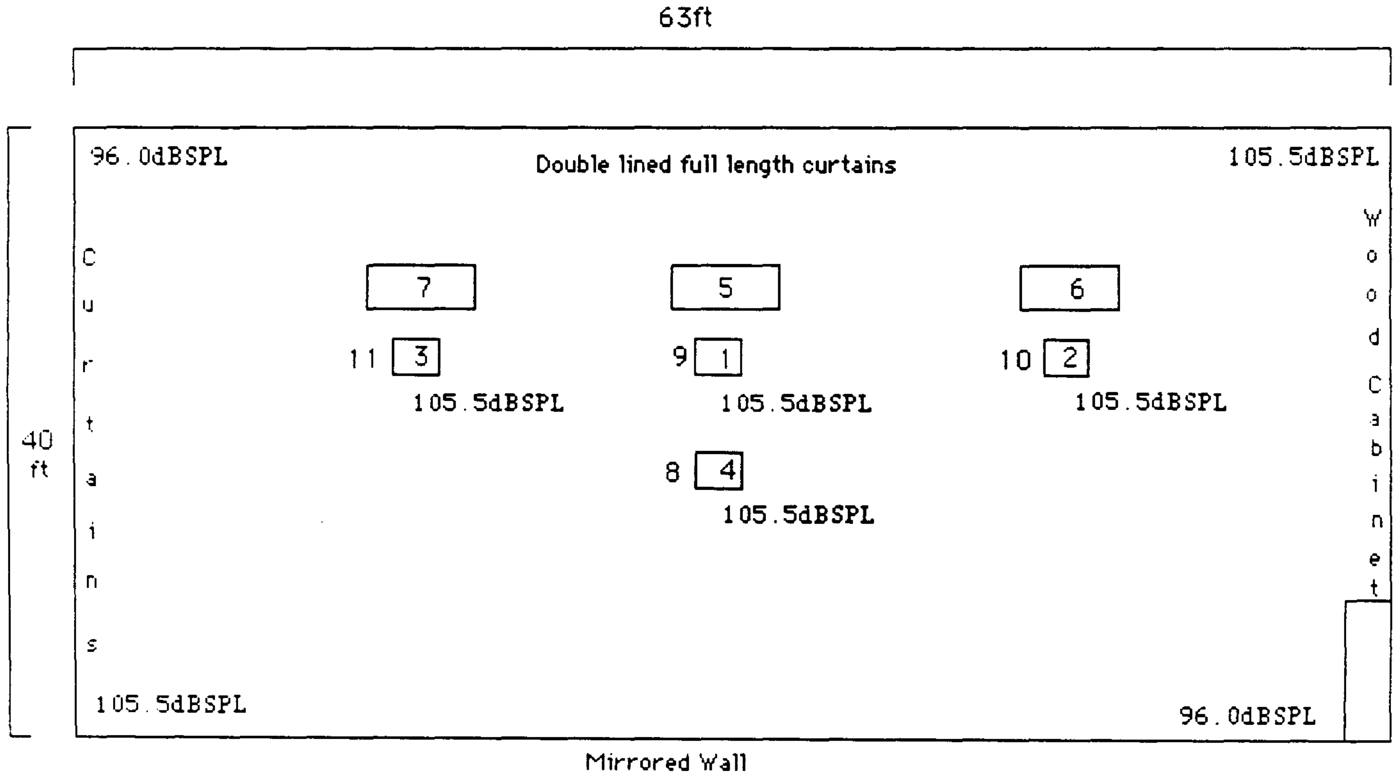
OTHER NOISE EXPOSURE	CAR STEREO	CAR STEREO GUNSHOTS	CONSTRUCTION	NO
USED HPDS FOR OTHER NOISE	NO	NO	FOAM PROTECTORS	NO

TABLE 2.

SUBJECTIVE IMPRESSIONS

SUBJECT	#1	#2	#3	#4
EARPLUGS EASY TO INSERT?	NO	NO	YES	SOMEWHAT
EARPLUGS COMFORTABLE?	NO	NO	NO	SOMEWHAT
EARPLUGS AFFECTED ABILITY TO PERFORM MUSICALLY?	YES	YES	YES	YES
IN WHAT WAYS?	HARDER TO HEAR	COULDN'T HEAR AS WELL	TIMING AND PRECISENESS OFF	------
PROBLEMS SUCH AS RINGING/ HEADACHES WITH EARPLUGS?	NO	NO	NO	NO
WILL WEAR WHEN PRACTICE AND PLAYOUT?	TRY AT PRACTICE/ PLAYOUT	TRY AT PRACTICE NOT WHEN PLAYING OUT	YES-PRACTICE NO-PLAYOUT	RARELY
OTHER COMMENTS	------	COULDN'T SMILE WITH PLUGS IN	COULDN'T TELL DIFFERENCE BETWEEN THESE AND FOAM PLUGS	IF YAWNED, MOVED FACE, RUBBED EYE: PLUG CAME LOOSE

Figure 1



1 = Subject 1
2 = Subject 2
3 = Subject 3
4 = Subject 4
5 = Peavey VTM 100 Halfstack Guitar Amplifier (100 Watts)
6 = Crate G150 Halfstack Guitar Amplifier (150 Watts)
7 = Peavey Combo 300 Bass Amplifier (300 Watts)
8 = Digitech Multi-Effects Processor
Digitech Harmonizer
Peavey Autograph Equalizer
9 = Gibson Les Paul Standard Guitar
10 = Gibson Les Paul Studio Guitar
11 = Gibson Bass Guitar

RESULTS

The pre-exposure and post-exposure thresholds and the mean temporary threshold shifts (TTSs) without earplugs from the first session are in Tables 3a and 3b and Figures 2a and 2b. The average amount of temporary threshold shift (TTS) for both ears in the lower frequencies of 250 and 500 Hz was 5.3dB. For the frequencies 1000 and 2000 Hz, the average TTS for both ears was 3.44dB. For the frequencies of 3000 and 4000 Hz, the average TTS for both ears was 8.13dB. For the higher frequencies of 6000 and 8000 Hz, the average TTS for both ears was -1.25dB. The average TTS for all frequencies in both ears was 7.81dB.

The pre-exposure and post-exposure thresholds and the mean temporary threshold shifts (TTSs) with earplugs from the second session are in Tables 4a and 4b and Figures 3a and 3b. For the lower frequencies of 250 and 500 Hz, the average TTS for both ears was 10dB. For the frequencies 1000 and 2000 Hz, the average TTS for both ears was 10.63dB. For the freqencies 3000 and 4000 Hz, the average TTS for both ears was 1.88dB. For the higher frequncies of 6000 and 8000 Hz, the average TTS for both ears was -1.88dB. The average TTS for all of the frequencies in both ears was 5.16dB.

Statistical analyses using the before and after hearing thresholds with and without earplugs are in Table 5. The post-exposure hearing thresholds were not significantly different from the pre-exposure thresholds with or without the earplugs at the frequencies 250, 3000, 4000, 6000, and 8000 Hz. The post-exposure hearing thresholds were significantly different ($p >.05$) from the pre-exposure hearing thresholds at the frequencies 500 and 2000 Hz with and without the earplugs. At 1000 Hz, there was a significant difference between the post- and pre-exposure hearing thresholds that was influenced by the earplugs being inserted but it was in the unexpected direction.

The attenuation effect of the ER-15 earplugs for the four subjects are in Tables 6a and 6b and Figures 4a and 4b.. The average difference between hearing thresholds with and without the ER-15 in both ears for the 250, 500, and 750 Hz frequencies was 7.71dB. The average difference for the frequencies 1000, 1500, and 2000 Hz was 12.08dB. The average difference for the frequencies 3000 and 4000 Hz was 12.5dB. The average difference for the higher frequencies of 6000 and 8000 Hz was 16.25dB.

Statistical analyses using the hearing thresholds without and with the ER-15 earplug to determine the attenuation effect are in Table 7. The thresholds without the earplug plus 15 should have equalled the threshold with the earplug in. There was no significant difference between the threshold without the earplug plus 15 and the threshold with the earplug in at any of the frequencies except 500 Hz. At 500 Hz, there was a significant difference ($p >.01$) between the threshold without the earplug plus 15 and the threshold with the earplug in.

TABLE 3a.

AMOUNT OF TEMPORARY THRESHOLD SHIFT WITHOUT EARPLUGS

RIGHT EAR

Subject	250			500			1K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	25	30	**5**	15	15	**0**	5	5	**0**
#2	5	15	**10**	0	15	**15**	0	5	**5**
#3	0	5	**5**	0	5	**5**	-5	0	**5**
#4	15	15	**0**	5	10	**5**	5	0	**-5**
x	11.25	16.25	**5**	5	11.25	**6.25**	1.25	2.5	**1.25**
	2K			3K			4K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	5	5	**0**	15	30	**15**	20	20	**0**
#2	-5	5	**10**	5	25	**20**	5	25	**20**
#3	-5	-5	**0**	5	10	**5**	0	5	**5**
#4	0	0	**0**	0	5	**5**	0	10	**10**
x	-1.25	1.25	**2.5**	6.25	17.5	**11.25**	6.25	15	**8.75**
	6K			8K					
	Pre	Post	**TTS**	Pre	Post	**TTS**			
#1	25	15	**-10**	20	5	**-15**			
#2	0	10	**10**	-10	10	**20**			
#3	5	15	**10**	-5	-5	**0**			
#4	5	10	**5**	5	-10	**-15**			
x	8.75	12.5	**3.75**	2.5	0	**-2.5**			

TABLE 3b.

AMOUNT OF TEMPORARY THRESHOLD SHIFT WITHOUT EARPLUGS

LEFT EAR

Subject	250			500			1K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	20	30	**10**	10	15	**5**	5	5	**0**
#2	5	15	**10**	0	15	**15**	0	5	**5**
#3	0	5	**5**	0	0	**0**	-5	0	**5**
#4	15	10	**-5**	5	5	**0**	0	0	**0**
x	10	15	**5**	3.75	8.75	**5**	0	2.5	**2.5**
	2K			3K			4K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	10	10	**0**	25	35	**10**	20	20	**0**
#2	-5	10	**15**	15	30	**15**	20	25	**5**
#3	-5	0	**5**	15	10	**-5**	0	5	**5**
#4	0	10	**10**	5	10	**5**	-5	10	**15**
x	0	7.5	**7.5**	15	21.25	**6.25**	8.75	15	**6.25**
	6K			8K					
	Pre	Post	**TTS**	Pre	Post	**TTS**			
#1	20	15	**-5**	20	10	**-10**			
#2	20	10	**-10**	-10	10	**20**			
#3	20	15	**-5**	-10	-5	**5**			
#4	20	10	**-10**	5	-5	**-10**			
x	20	12.5	**-7.5**	1.25	2.5	**1.25**			

FIGURE 2a.

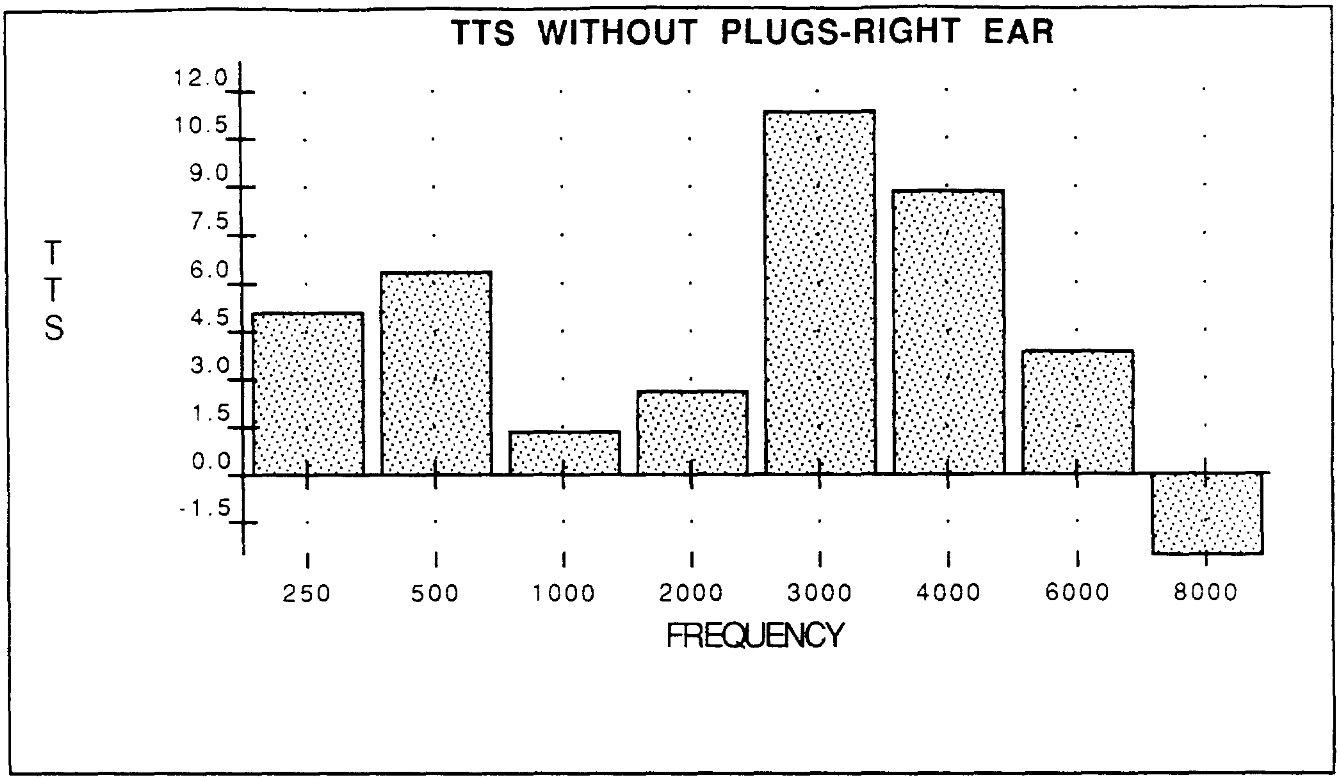


FIGURE 2b.

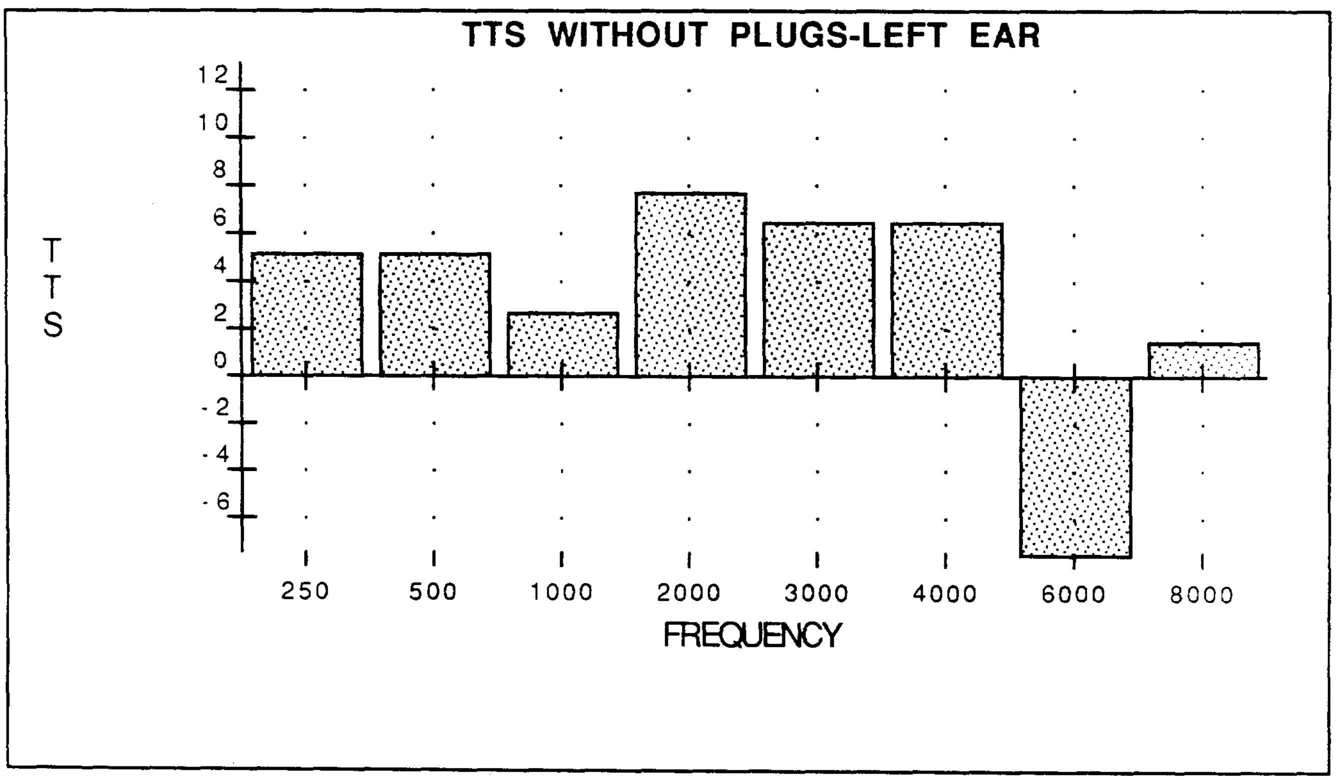


TABLE 4a.

AMOUNT OF TEMPORARY THRESHOLD SHIFT WITH EARPLUGS IN

RIGHT EAR

Subject	250			500			750		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	15	30	**15**	5	35	**30**	5	30	**25**
#2	10	10	**0**	10	25	**15**	0	20	**20**
#3	5	15	**10**	5	25	**20**	5	25	**20**
#4	10	20	**10**	5	10	**5**	5	20	**15**
x	10	18.75	**8.75**	6.25	23.75	**17.5**	3.75	23.75	**20**
	1K			1.5K			2K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	0	30	**30**	0	15	**15**	-5	10	**15**
#2	0	15	**15**	0	15	**15**	5	10	**5**
#3	-5	15	**20**	5	15	**10**	-5	5	**10**
#4	5	20	**15**	0	15	**15**	-5	5	**10**
x	0	20	**20**	1.25	15	**13.75**	-2.5	7.5	**10**
	3K			4K			6K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	15	20	**5**	15	15	**0**	15	15	**0**
#2	5	5	**0**	5	10	**5**	0	0	**0**
#3	5	5	**0**	0	5	**5**	5	20	**15**
#4	0	5	**5**	-5	0	**5**	15	10	**-5**
x	6.25	8.75	**2.5**	3.75	7.5	**3.75**	8.75	11.25	**2.5**
	8K								
	Pre	Post	**TTS**						
#1	25	10	**-15**						
#2	5	-5	**-10**						
#3	10	10	**0**						
#4	-5	0	**5**						
x	8.75	3.75	**-5**						

TABLE 4b.

AMOUNT OF TEMPORARY THRESHOLD SHIFT WITH EARPLUGS IN

LEFT EAR

Subject	250			500			750		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#!	20	30	**10**	20	30	**10**	15	30	**15**
#2	10	15	**5**	10	20	**10**	5	20	**15**
#3	15	15	**0**	10	15	**5**	10	20	**10**
#4	15	15	**0**	5	20	**15**	5	20	**15**
x	15	18.75	**3.75**	11.25	21.25	**10**	8.75	22.5	**13.75**
	1K			1.5K			2K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	5	25	**20**	0	15	**15**	5	5	**0**
#2	5	10	**5**	5	10	**5**	0	5	**5**
#3	0	10	**10**	5	10	**5**	5	5	**0**
#4	0	10	**10**	0	5	**5**	5	5	**0**
x	2.5	13.75	**11.25**	2.5	10	**7.5**	3.75	5	**1.25**
	3K			4K			6K		
	Pre	Post	**TTS**	Pre	Post	**TTS**	Pre	Post	**TTS**
#1	25	20	**-5**	25	25	**0**	15	15	**0**
#2	15	15	**0**	15	25	**10**	30	15	**-15**
#3	15	15	**0**	0	10	**10**	20	15	**-5**
#4	5	0	**-5**	5	0	**-5**	5	15	**10**
x	15	12.5	**-2.5**	11.25	15	**3.75**	17.5	15	**-2.5**
	8K								
	Pre	Post	**TTS**						
#1	5	10	**5**						
#2	-5	-10	**-5**						
#3	10	0	**-10**						
#4	0	0	**0**						
x	2.5	0	**-2.5**						

FIGURE 3a.

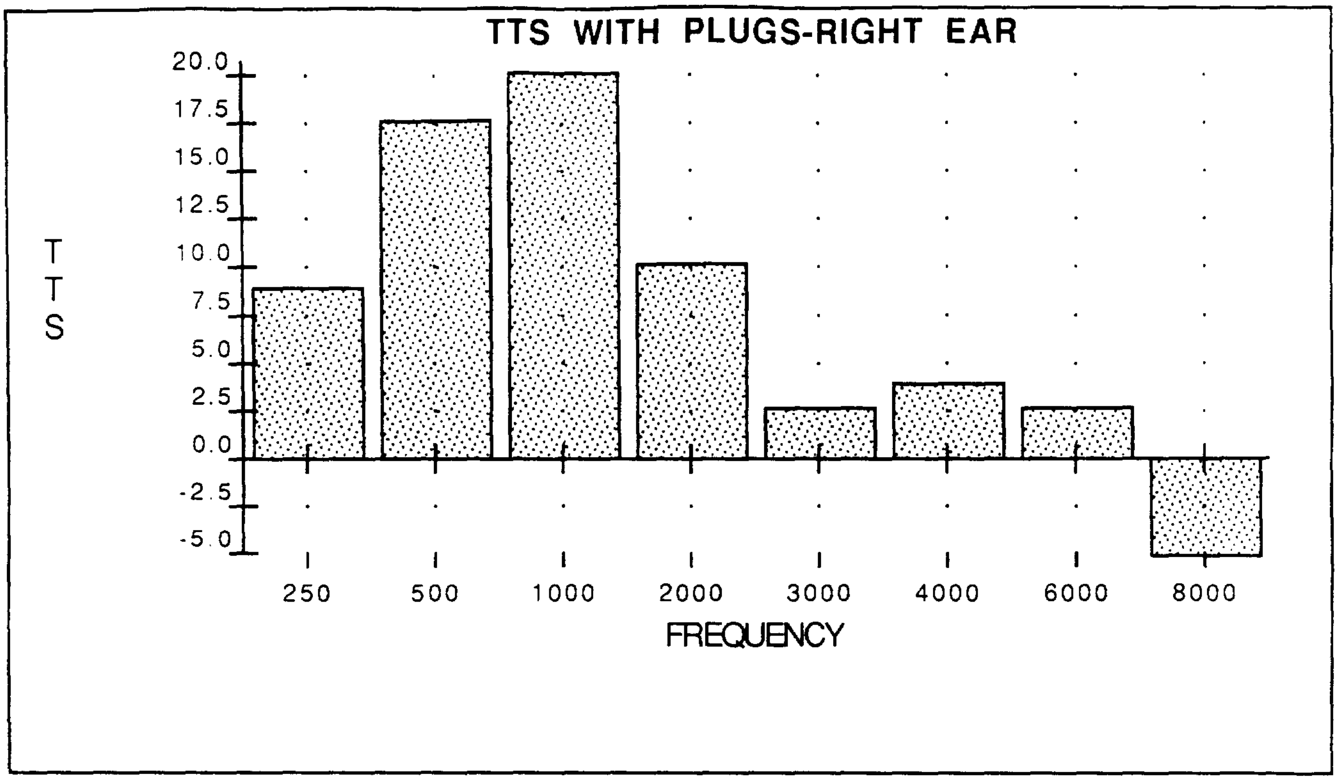


FIGURE 3b.

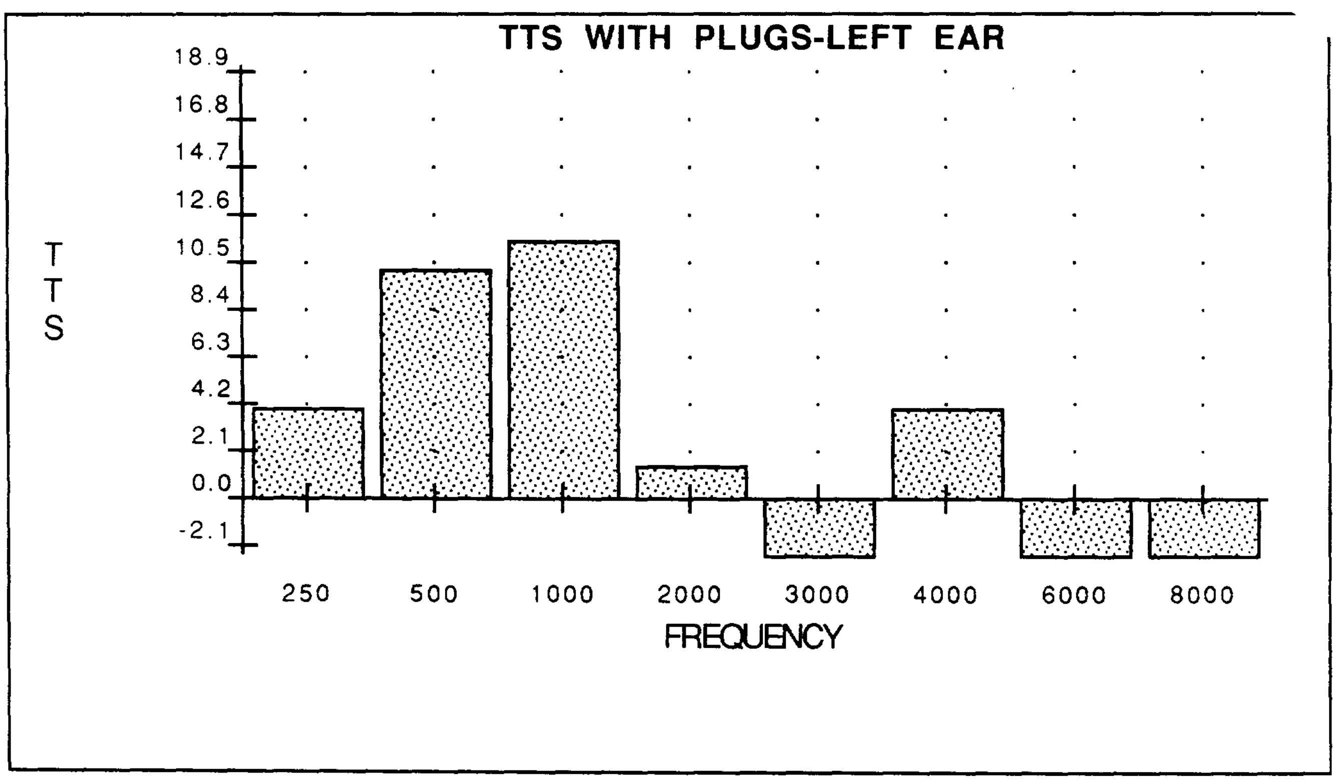


		TABLE 5.							
		MUSIC EFFECT WITH AND WITHOUT EARPLUG							
Variable	Mean	Std. Dev	N	Source Var	SS	DF	MS	F	Sig of F
P250B	12.5	3.536	4	Within cells	39.06	3	13.02		
P250A	18.75	7.773	4	When	126.56	1	126.56	9.72	0.053
N250B	10.625	10.078	4	Within cells	32.81	3	10.94		
N250A	15.625	10.483	4	Plug by when	1.56	1	1.56	0.14	0.731
P500B	8.75	3.227	4	Within cells	35.55	3	11.85		
P500A	22.5	7.36	4	When	375.39	1	375.39	31.68	0.011
N500B	4.375	5.907	4	Within cells	51.17	3	17.06		
N500A	10	6.124	4	Plug by when	66.02	1	66.02	3.87	0.144
P1KB	1.25	2.5	4	Within cells	31.25	3	10.42		
P1KA	16.875	7.181	4	When	306.25	1	306.25	29.4	0.012
N1KB	0.625	4.27	4	Within cells	34.69	3	18.23		
N1KA	2.5	2.887	4	Plug by when	189.06	1	189.06	10.37	0.049
P2KB	0.625	1.25	4	Within cells	16.8	3	5.6		
P2KA	6.25	1.443	4	When	112.89	1	112.89	20.16	0.021
N2KB	-0.625	5.907	4	Within cells	29.3	3	9.77		
N2KA	4.375	4.732	4	Plug by when	0.39	1	0.39	0.04	0.854
P3KB	10.625	7.181	4	Within cells	45.31	3	15.1		
P3KA	10.625	7.181	4	When	76.56	1	76.56	5.07	0.11
N3KB	10.625	7.181	4	Within cells	45.31	3	15.1		
N3KA	19.375	12.479	4	Plug by when	76.56	1	76.56	5.07	0.11
P4KB	7.5	9.574	4	Within cells	51.56	3	17.19		
P4KA	11.25	9.242	4	When	126.56	1	126.56	7.36	0.073
N4KB	7.5	10.607	4	Within cells	32.81	3	10.94		
N4KA	15	9.129	4	Plug by when	14.06	1	14.06	1.29	0.339
P6KB	13.125	2.394	4	Within cells	38.67	3	12.89		
P6KA	13.125	4.27	4	When	3.52	1	3.52	0.27	0.638
N6KB	14.375	5.543	4	Within cells	32.42	3	10.81		
N6KA	12.5	2.887	4	Plug by when	3.52	1	3.52	0.33	0.608
P8KB	5.625	8.26	4	Within cells	123.05	3	41.02		
P8KA	1.875	7.465	4	When	19.14	1	19.14	0.47	0.544
N8KB	1.875	13.75	4	Within cells	263.67	3	87.89		
N8KA	1.25	8.78	4	Plug by when	9.77	1	9.77	0.11	0.761

TABLE 6a.

ATTENUATION EFFECTS OF THE ER-15 EARPLUG

RIGHT EAR

Subject	250			500			750		
	w/o	w	**dif**	w/o	w	**dif**	w/o	w	**dif**
#1	15	20	**5**	5	10	**5**	5	15	**10**
#2	10	20	**10**	10	20	**10**	0	10	**10**
#3	5	20	**15**	5	15	**10**	5	20	**15**
#4	10	15	**5**	5	10	**5**	5	10	**5**
x	10	18.75	**8.75**	6.25	13.75	**7.5**	3.75	13.75	**10**
	1K			1.5K			2K		
	w/o	w	**dif**	w/o	w	**dif**	w/o	w	**dif**
#1	0	15	**15**	0	15	**15**	-5	15	**20**
#2	0	10	**10**	0	15	**15**	5	10	**5**
#3	-5	10	**15**	5	15	**10**	-5	10	**15**
#4	5	10	**5**	0	10	**10**	-5	10	**15**
x	0	11.25	**11.25**	1.25	13.75	**12.5**	-2.5	11.25	**13.75**
	3K			4K			6K		
	w/o	w	**dif**	w/o	w	**dif**	w/o	w	**dif**
#1	15	30	**15**	15	25	**10**	15	25	**10**
#2	5	20	**15**	5	25	**20**	0	20	**20**
#3	5	20	**15**	0	15	**15**	5	35	**30**
#4	0	10	**10**	-5	10	**15**	15	20	**5**
x	6.25	20	**13.75**	3.75	18.75	**15**	8.75	25	**16.25**
	8K								
	w/o	w	**dif**						
#1	25	20	**-5**						
#2	5	35	**30**						
#3	10	45	**35**						
#4	-5	20	**25**						
x	8.75	30	**21.25**						

w/o = earplug not inserted

w = earplug inserted

dif = difference in threshold

TABLE 6b.

ATTENUATION EFFECTS OF THE ER-15 EARPLUG

LEFT EAR

Subject	250			500			750		
	w/o	w	**dif**	w/o	w	**dif**	w/o	w	**dif**
#1	20	30	**10**	20	25	**5**	15	25	**10**
#2	10	20	**10**	10	15	**5**	5	15	**10**
#3	15	20	**5**	10	20	**10**	10	25	**15**
#4	15	10	**-5**	5	10	**5**	5	5	**0**
x	15	20	**5**	11.25	17.5	**6.25**	8.75	17.5	**8.75**
	1K			1.5K			2K		
	w/o	w	**dif**	w/o	w	**dif**	w/o	w	**dif**
#1	5	15	**10**	0	15	**15**	5	15	**10**
#2	5	15	**10**	5	20	**15**	0	10	**10**
#3	0	15	**15**	5	20	**15**	5	15	**10**
#4	0	10	**10**	0	10	**10**	5	15	**10**
x	2.5	13.75	**11.25**	2.5	16.25	**13.75**	3.75	13.75	**10**
	3K			4K			6K		
	w/o	w	**dif**	w/o	w	**dif**	w/o	w	**dif**
#1	25	35	**10**	25	35	**10**	15	25	**10**
#2	15	30	**15**	15	30	**15**	30	25	**-5**
#3	15	25	**10**	0	15	**15**	20	30	**10**
#4	5	15	**10**	5	5	**0**	5	20	**15**
x	15	26.25	**11.25**	11.25	21.25	**10**	17.5	25	**7.5**
	8K								
	w/o	w	**dif**						
#1	5	30	**25**						
#2	-5	10	**15**						
#3	10	40	**30**						
#4	0	10	**10**						
x	2.5	22.5	**20**						

w/o = earplug not inserted

w = earplug inserted

dif = difference in threshold

FIGURE 4a.

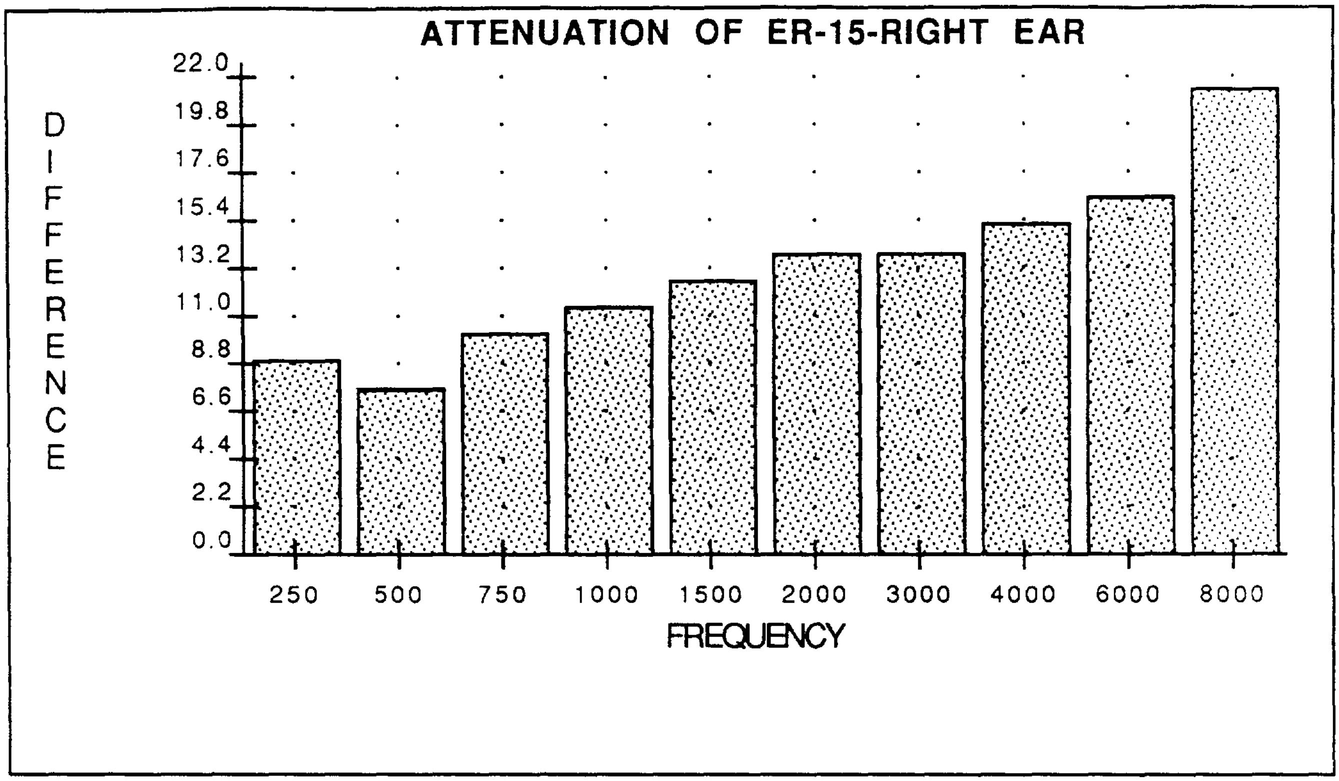
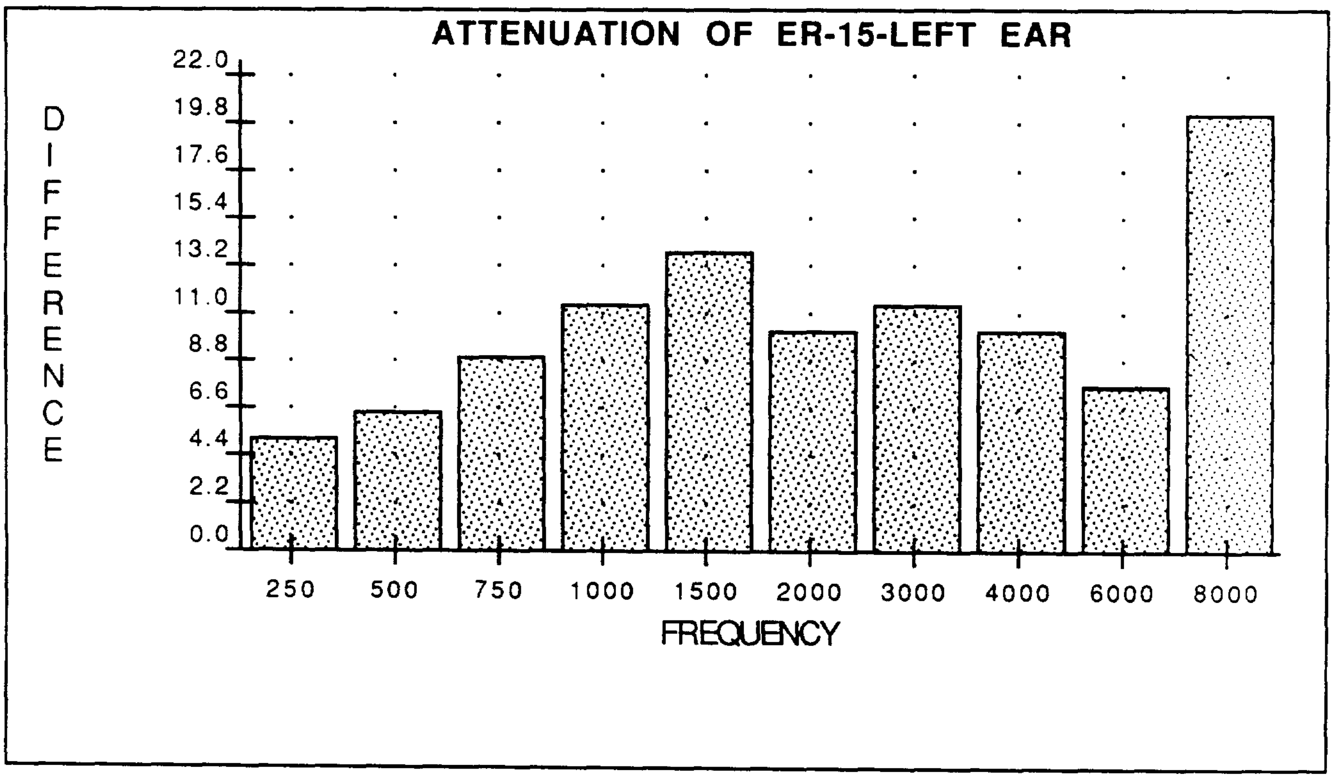


FIGURE 4b.



)))

TABLE 7.

ATTENUATION EFFECT OF THE ER-15 EARPLUG

t-tests for paired samples

Variable	# of cases	Mean	Standard Dev.	Standard Error	Difference Mean	Difference Standard Dev.	Difference Standard Error	Corr.	2-tail Prob.	t Value	Deg. of Freedom	2-tail prob.	1-tail prob.	Significant/Not
P250	4	19.375	5.154	2.577										
N250	4	27.5	3.536	1.768	-8.125	4.732	2.366	0.457	0.543	-3.43	3	0.041	0.02	Not
P500	4	15.625	3.75	1.875										
N500	4	23.75	3.227	1.614	-8.125	2.394	1.197	0.775	0.225	-6.79	3	0.007	0.0035	Significant
P750	4	15.625	6.884	3.442										
N750	4	21.25	3.227	1.614	-5.625	5.154	2.577	0.703	0.297	-2.18	3	0.117	0.0585	Not
P1K	4	12.5	2.041	1.021										
N1K	4	16.25	2.5	1.25	-3.75	3.227	1.614	.000	1	-2.32	3	0.103	0.0515	Not
P1.5K	4	15	3.536	1.768										
N1.5K	4	16.875	2.394	1.197	-1.875	2.394	1.197	0.739	0.261	-1.57	3	0.215	0.1075	Not
P2K	4	12.5	2.041	1.021										
N2K	4	15.625	1.25	0.625	-3.125	3.146	1.573	-0.816	0.184	-1.99	3	0.141	0.0705	Not
P3K	4	23.125	8.26	4.13										
N3K	4	25.625	7.181	3.59	-2.5	2.041	1.021	0.975	0.025	-2.45	3	0.092	0.046	Not
P4K	4	20	10.607	5.303										
N4K	4	22.5	9.574	4.787	-2.5	4.564	2.282	0.903	0.097	-1.1	3	0.353	0.1765	Not
P6K	4	25	5.401	2.7										
N6K	4	28.125	2.394	1.197	-3.125	5.543	2.772	0.161	0.839	-1.13	3	0.342	0.171	Not
P8K	4	26.25	11.637	5.818										
N8K	4	20.625	8.26	4.13	5.625	9.437	4.719	0.596	0.404	1.19	3	0.319	0.1595	Not

DISCUSSION

The pre- and post-exposure thresholds without earplugs showed that the average TTS for the low frequencies of 250 and 500 Hz was 5.31dB. At 1000 and 2000 Hz, the average TTS was 3.44dB. At 3000 and 4000 Hz, the average TTS was 8.13dB. For the high frequencies of 6000 and 8000 Hz, the average TTS was -1.25. The average TTS for all frequencies in both ears was 7.81dB. Due to the sound pressure level of 105.5dB at the ear of each subject, a TTS without the earplugs was expected. In the right ear, the TTS was substantially greater at 3000 Hz. In the left ear, this difference was not observed. The 3000 Hz frequency is commonly affected by noise exposure. Perhaps the TTS was greater in the right ear because the musicians stood with their right ears toward the amplifiers most of the time while playing. At 6000 and 8000 Hz, some negative TTS was observed which meant that the subjects' hearing thresholds were actually better after playing. This may have occurred because only two subjects could be tested at a time due to equipment limitations. The other two subjects could have recovered some hearing before being tested. The subjects may also have been more familiar with the testing procedure and knew what they were listening for the second time their thresholds were measured.

The pre- and post-exposure thresholds with the earplugs showed an average TTS of 10dB at 250 and 500 Hz. The average TTS at 1000 and 2000 Hz was 10.63dB. At 3000 and 4000 Hz, the average TTS was 1.88dB. For the high frequencies of 6000 and 8000 Hz, the average TTS was -1.88dB. The average TTS for all frequencies in both ears was 5.16dB. Less of a TTS was expected with the earplugs in than without . The average TTS for all frequencies was lower with the earplugs than without (5.16 < 7.81). Comparing individual frequencies, however, showed inconsistent results. For some frequencies, the TTS with the earplugs was actually greater than without the earplugs especially in the lower frequencies. One possible explanation for these unexpected results may be that the post-exposure thresholds after wearing the earplugs were not taken in an IAC sound-treated room. Threshold measurements were taken in the same room immediately after playing to reduce recovery time. Background noise was present and was more likely to affect the ability to hear low frequencies than high. The subjects commented on the subjective impression questionnaires that the earplugs came loose if they moved their faces when smiling or yawning. When this happened, they readjusted the earplugs. Therefore, the earplugs may not have been properly inserted and sealed for the entire time they were playing.

Statistical analyses showed that the post-exposure thresholds were not significantly different from the pre-exposure thresholds with or without the earplugs at 250, 3000, 4000, 6000, and 8000 Hz. This meant that at these frequencies the pre- and post-exposure thresholds were about the same whether the earplugs were in or out. The post-exposure thresholds at 500 and 2000 Hz were significantly different from the pre-exposure thresholds with and without the earplugs. At these frequencies, the post-exposure threshold was worse whether or not the earplugs were in or out. At 1000 Hz there was a significant difference between pre- and post-exposure thresholds that was influenced by the earplug being inserted. However, the post-exposure was worse with the earplug in.

The attenuation effect of the ER-15 earplug was determined by the difference between hearing thresholds with and without the earplug. At 250, 500, and 750 Hz, the average difference was 7.71dB. At 1000, 1500, and 2000 Hz, the average difference was 12.08dB. The average difference at 3000 and 4000 Hz was 12.5dB. At the high frequencies of 6000 and 8000 Hz, the average difference was 16.25dB. The ER-15 custom-made musician's earplug was designed to provide 15dB of attenuation at each frequency. These results do not support that research. Attenuation increased as frequency increased. The attenuation provided was not as great in the low frequencies. This may also explain why a greater TTS was observed in the low frequencies with the earplugs in than in the high frequencies. The higher frequencies were getting more attenuation and therefore had less TTS.

Statistical analyses showed that there was no significant difference between the threshold without the earplug plus 15 and the threshold with the earplug in at any frequency except 500 Hz. Even though the differences were not always 15dB, they were not significantly different. Therefore, the ER-15 earplug provided the appropriate amount of attenuation for which it was designed at all of the octave frequencies from 250 to 8000 Hz with the exception of 500 Hz. This exception may be due to the small sample size used in this study. Due to the cost of the earplugs, only four subjects could be studied. The lack of appropriate attenuation at 500 Hz may explain why there was a significant difference between pre- and post-exposure thresholds even with the earplug inserted.

Several of the problems encountered during this research project could not have been foreseen before the study was begun. Some of the results seemed inconsistent and inaccurate. As discussed previously, this may have been due to several factors. The small sample size was one limitation to this study. The testing equipment limitations were also a factor. Only two IAC sound-treated rooms were available, and they were not close to the practice room where the musicians played. This allowed recovery time. When testing in the practice room, the thresholds may have been inaccurate due to the presence of background noise. Another factor involved was the proper insertion of the ER-15 earplugs. The subjects' comments concerning the movement of their faces and the loosening of the earplugs make it likely that the earplugs were not properly inserted for the whole playing time.

The underlying purpose of this honors thesis was to learn something about the process of research. The author has learned that there were many things that developed during the research process that were not foreseen and probably could not have been prevented. The author has also learned that despite careful planning and organization, there were some things that the experimenter could not control. The author better understands how several studies on the same topic could get very different results depending upon the various factors that can influence research.

Research is a vital part of our world today. Its value and contribution to society should not be taken for granted. However, research results must be presented clearly and accurately even when they are not what the researcher was expecting or hoping to find. The public should not believe everything researchers claim to be true without questioning and examining their methods, procedures, and results for itself.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr. Claudia Updike, Dr. Mead Killion, Etymotic Research, Mr. Lloyd Bookmyer, Robert Mahle, Norman Porter, Heath Hopkins, Dean Meyer, and William Mack for their personal and financial contributions. Thank you for sharing your knowledge, skill, and cooperation with me.

REFERENCES

Berger, E.H., Ward, W.D., Morrill, J.C., & Royster, L.H. (Eds.). (1986). Noise and Hearing Conservation Manual. Akron: American Industrial Hygiene Association.

Etymotic Research. (1991). Solutions Provided: ER-15 Musician Earplug and ER-20 Hi-Fi Earplug. Elk Grove Village, IL.

Jerger, J. and Jerger, S. (1970). Temporary Threshold Shift in Rock and Roll Musicians. Journal of Speech and Hearing Research 13, 218-224.

Johnson, D.W., Aldridge, J., Sherman, R.E., & Lorraine, A. (1986). Extended High Frequency Hearing Sensitivity: A Normative Threshold Study in Musicians. Annals of Otology, Rhinology, and Laryngology 95, 196-202.

Karlsson, K., Lundquist, P.G., & Olaussen, T. (1983). The Hearing of Symphony Orchestra Musicians. Scandinavian Audiology 12, 257-264.

Killion, M., DeVilbiss, E., & Steward, J. (1988). An Earplug With Uniform 15dB Attenuation. The Hearing Journal May, 14-17.

Ostri, B., Ellar, N., Dahlin, E., & Skylv, G. (1989). Hearing Impairment in Orchestral Musicians. Scandinavian Audiology 18, 243-249.

APPENDICES

APPENDIX A

AMOUNT OF TEMPORARY THRESHOLD SHIFT WITH EARPLUGS

RIGHT EAR

Subject	250		500		750		1K		1.5K		2K		3K		4K		6K		8K	
#1	15	30	5	35	5	30	0	30	0	15	-5	10	15	20	15	15	15	15	25	10
#2	10	10	10	25	0	20	0	15	0	15	5	10	5	5	5	10	0	0	5	-5
#3	5	15	5	25	5	25	-5	15	5	15	-5	5	5	5	0	5	5	20	10	10
#4	10	20	5	10	5	20	5	20	0	15	-5	5	0	5	-5	0	15	10	-5	0

LEFT EAR

#1	20	30	20	30	15	30	5	25	0	15	5	5	25	20	25	25	15	15	5	10
#2	10	15	10	20	5	20	5	10	5	10	0	5	15	15	15	25	30	15	-5	-10
#3	15	15	10	15	10	20	0	10	5	10	5	5	15	15	0	10	20	15	10	0
#4	15	15	5	20	5	20	0	10	0	5	5	5	5	0	5	0	5	15	0	0

AMOUNT OF TEMPORARY THRESHOLD SHIFT WITHOUT EARPLUGS

RIGHT EAR

Subject	250		500		750		1K		1.5K		2K		3K		4K		6K		8K	
#1	25	30	15	15			5	5			5	5	15	30	20	20	25	15	20	5
#2	5	15	0	15			0	5			-5	5	5	25	5	25	0	10	-10	10
#3	0	5	0	5			-5	0			-5	-5	5	10	0	5	5	15	-5	-5
#4	15	15	5	10			5	0			0	0	0	5	0	10	5	10	5	-10

LEFT EAR

#1	20	30	10	15			5	5			10	10	25	35	20	20	20	15	20	10
#2	5	15	0	15			0	5			-5	10	15	30	20	25	20	10	-10	10
#3	0	5	0	0			-5	0			-5	0	15	10	0	5	20	15	-10	-5
#4	15	10	5	5			0	0			0	10	5	10	-5	10	20	10	5	-5

APPENDIX B

HEARING THRESHOLDS WITH AND WITHOUT THE ER-15 EARPLUG

RIGHT EAR

Subject	250		500		750		1K		1.5K		2K		3K		4K		6K		8K	
#1	15	20	5	10	5	15	0	15	0	15	-5	15	15	30	15	25	15	25	25	20
#2	10	20	10	20	0	10	0	10	0	15	5	10	5	20	5	25	0	20	5	35
#3	5	20	5	15	5	20	-5	10	5	15	-5	10	5	20	0	15	5	35	10	45
#4	10	15	5	10	5	10	5	10	0	10	-5	10	0	10	-5	10	15	20	-5	20

LEFT EAR

	250		500		750		1K		1.5K		2K		3K		4K		6K		8K	
#1	20	30	20	25	15	25	5	15	0	15	5	15	25	35	25	35	15	25	5	30
#2	10	20	10	15	5	15	5	15	5	20	0	10	15	30	15	30	30	25	-5	10
#3	15	20	10	20	10	25	0	15	5	20	5	15	15	25	0	15	20	30	10	40
#4	15	10	5	10	5	5	0	10	0	10	5	15	5	15	5	5	5	20	0	10

APPENDIX C

THRESHOLDS BEFORE PRACTICING

RIGHT EAR

February

Subject	250	500	750	1K	1.5K	2K	3K	4K	6K	8K
#1	25	15		5		5		20	25	20
#2	5	0		0		-5		5		-10
#3	0	0		-5		-5		0		-5
#4	15	5		5		0		0	5	5

May

	250	500	750	1K	1.5K	2K	3K	4K	6K	8K
#1	15	5	5	0	0	-5	15	15	15	25
#2	10	10	0	0	0	5	5	5	0	5
#3	5	5	5	-5	5	-5	5	0	5	10
#4	10	5	5	5	0	-5	0	-5	15	-5

AMOUNT OF THRESHOLD DIFFERENCE BETWEEN FEBRUARY AND MAY

Subject	250	500	750	1K	1.5K	2K	3K	4K	6K	8K
#1	10	10		5		10		5	10	5
#2	5	10		0		10		0		15
#3	5	5		0		0		0		15
#4	5	0		0		5		5	10	10

APPENDIX D

THRESHOLDS BEFORE PRACTICING

LEFT EAR

February

Subject	250	500	750	1K	1.5K	2K	3K	4K	6K	8K
#1	20	10		5		10		20	20	20
#2	5	0		0		-5		20		-10
#3	0	0		-5		-5		0		-10
#4	15	5		0		0		5-	20	5

May

	250	500	750	1K	1.5K	2K	3K	4K	6K	8K
#1	20	20	15	5	0	5	25	25	15	5
#2	10	10	5	5	5	0	15	15	30	-5
#3	15	10	10	0	5	5	15	0	20	10
#4	15	5	5	0	0	5	5	5	5	0

AMOUNT OF THRESHOLD DIFFERENCE BETWEEN FEBRUARY AND MAY

	250	500	750	1K	1.5K	2K	3K	4K	6K	8K
#1	0	10		0		5		5	5	15
#2	5	10		5		5		5		5
#3	15	10		5		10		0		20
#4	0	0		0		0		10	15	5